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*Publication date:*  
2018

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Loaldi, D., Zhang, Y., Calaon, M., Yang, Y., Guo, P., Garnæs, J., & Tosello, G. (2018). *Pitch measurements validation of steel inserts microgrooves with light diffractive properties using a Laser Scanning Confocal Microscope (LSCM) and an Atomic Force Microscope (AFM)*. Poster session presented at 18th International Conference of the European Society for Precision Engineering and Nanotechnology (euspen 18), Venice, Italy.

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# Pitch measurements validation of steel inserts micro-grooves with light diffractive properties using a Laser Scanning Confocal Microscope (LSCM) and an Atomic Force Microscope (AFM)

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## Abstract

The optical principle of structural colouration provides to a surface unnatural and iridescent colouring properties. Surface topography combined with lighting characteristics are the physical driver of the phenomenon. Structural colouring arises from the presence on the specimen of nanoscale features distanced by a length comparable to the near visible light spectrum (300-1000 nm). The micro structures behave as a band-pass filter for certain light wavelengths, enabling an unnatural colouring effect. Elliptical Vibration Texturing (EVT) is an on development technology for fast texturing of gratings on metal inserts for structural colouration purposes.

To identify the accuracy of EVT, in this study, two different microscopes assess an EVT grating with a 1000 nm nominal pitch on a steel flat surface.

On first, optical-based metrology is selected adopting a Laser Scanning Confocal Microscope (SCM) with a 405 nm blue source to tackle the measuring purpose. Secondly, an Atomic Force Microscope (AFM) in Intermittent contact mode (IC-AFM) is adopted. Considering the differences in set-up time and scanning range, the objective of this research is to identify the most favourable measuring technique.

On the sample images, five average profiles on different locations provide consistent information about the process repeatability. Pitch estimation comes by means of FFT algorithm on the extracted profiles. The average result for SCM measures is  $1002 \pm 31$  nm while for AFM is  $972 \pm 15$  nm. At last, from these results, the estimation of EVT accuracy is presented.

Scanning Confocal Microscopy, Dynamic Force Microscopy, Elliptical Vibration Texturing, Structural Colouration

## Elliptical Vibration Texturing (EVT)

- Objective  $\Rightarrow$  Texture bio-inspired structural colours [1].
- Task  $\Rightarrow$  Generate a periodic grating with a nominal pitch of 1000 nm [2].

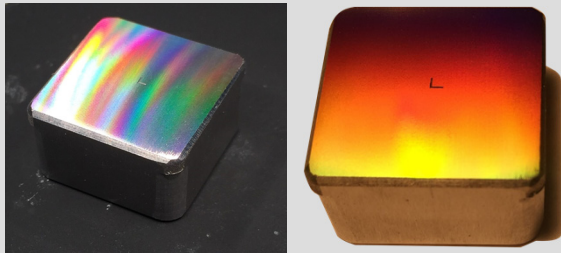


Fig. 1: 20 mm x 20 mm x 10 mm steel insert with light diffractive properties [3]

## Metrology

- Objective  $\Rightarrow$  Compare Scanning Confocal Microscopy (SCM) and Atomic Force Microscopy (AFM)

- Task  $\Rightarrow$  Evaluate pitch of the periodic grating.
- Procedure  $\Rightarrow$  1. Cut FOV to  $80 \times 80 \mu\text{m}^2$ .  
2. Resize to  $4096 \times 256$  pixels<sup>2</sup>.  
3. Levelling with Least Square plane.  
4. Pitch estimation with FFT.  
5. Uncertainty calculated with GUM [4,5].

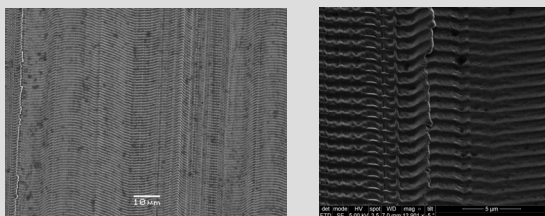


Fig. 2: Different magnification of the grating surface by means of SEM

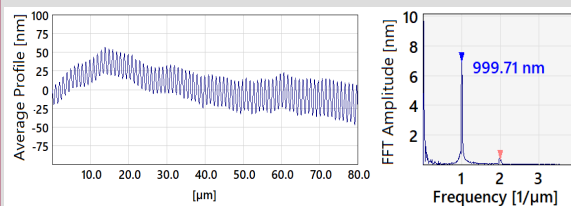


Fig. 3: Average profile (left) and dominant pitch estimation (right)

## Conclusion

In this study, two measuring strategies undertake the challenge of measuring 1000 nm nominal pitch gratings of a structural coloured steel insert. SCM shows a consistent result with AFM used in Dynamic Force Microscopy setting. The expanded uncertainty calculated for SCM is almost twice as large than the AFM one, due to calibration and physical principal. However, measuring time is significantly smaller for SCM than AFM. A final consideration from this study provides EVT average process accuracy to the below 30 nm range.

## Scanning Confocal Microscopy

High magnification objective (50x)

Working Distance (WD)	350 $\mu\text{m}$
Numerical Aperture (NA)	0.95
Field of View (FoV)	$259 \times 259 \mu\text{m}^2$
Repeated measurements	10
Image resolution	$4096 \times 4096$ pixels <sup>2</sup>
Pixel size	63 nm
Set-up time	15 min
Measurement time	5 min

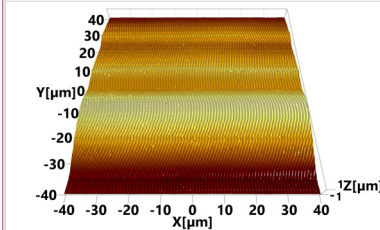


Fig. 4: Image Sampled with SCM

## Atomic Force Microscope

Intermittent contact mode (IC-AFM)

Vertical oscillation Amplitude	20 nm
Horizontal scanning speed	8 $\mu\text{m/s}$
Scanning area	$80 \times 80 \mu\text{m}^2$
Repeated measurements	5
Image resolution	$4096 \times 256$ pixels <sup>2</sup>
Pixel size	$20 \times 313$ nm
Set-up time	60 min
Measurement time	43 min

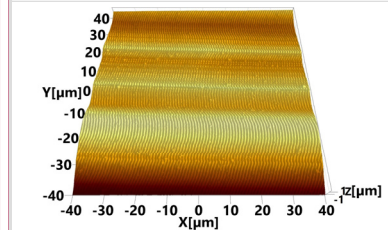


Fig. 5: Image sampled with AFM

## Measurements results and comparison

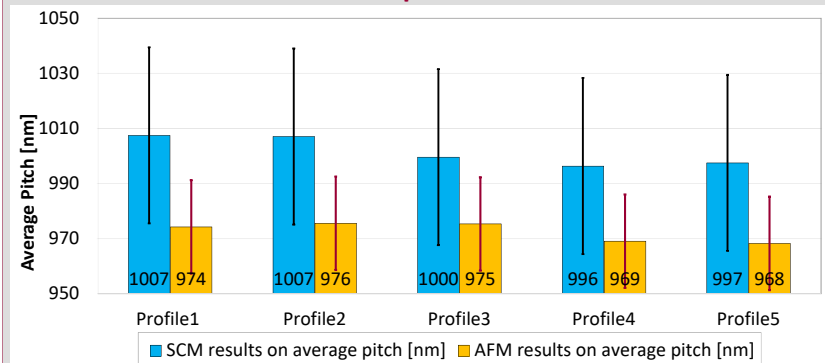


Fig. 5: Average and uncertainty of pitch estimation calculated on the SCM (a) and AFM (b)

## Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 767589. PROSURF ("Surface Specifications and Process Chains for Functional Surfaces"). This project has received funding from the Danish Innovation Fund (<https://innovationsfonden.dk/en>), in the research project of MADE DIGITAL, Manufacturing Academy of Denmark (<http://en.made.dk/>), Work Package WP3 "Digital manufacturing processes". The work has been supported by funds from the Danish Agency for Institutions and Educational Grants.

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